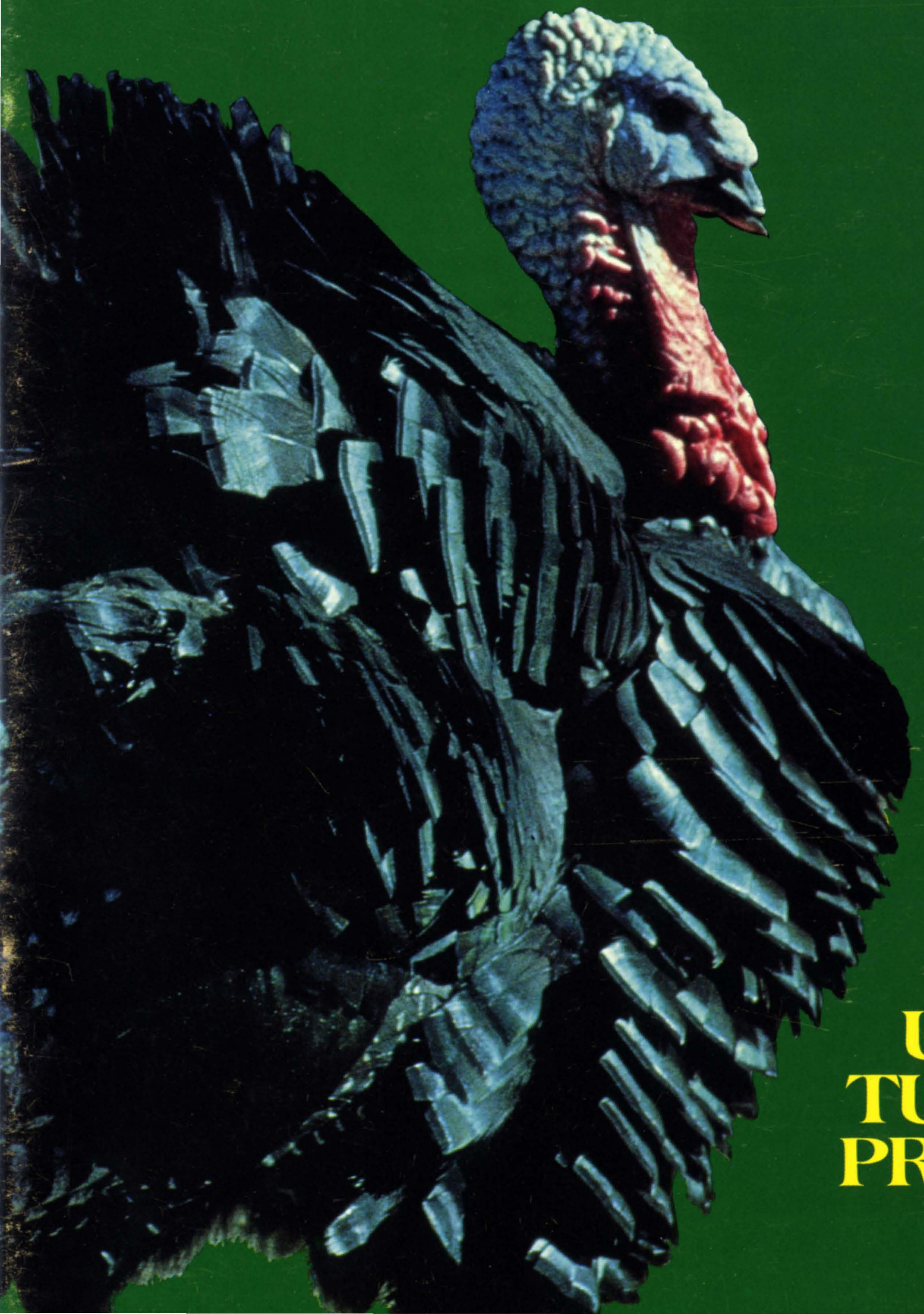
Utah Science Vol. 40 No. 4, December 1979

UTAH AGRICULTURAL EXPERIMENT STATION WINTER 1979 VOLUME 40 NUMBER 4

UTAH SCIENCE



UTAH TURKEY PROFILE

WINTER 1979 VOLUME 40 NUMBER 4

UTAH SCIENCE

UTAH AGRICULTURAL EXPERIMENT STATION

ABOUT THE COVER

The bronze turkey is favored for its sumptuous feathers highlighted by iridescent greens. The white turkey was chosen to be bred for meat; traditionally having been preferred by cooks as it lacks pigment in the pinfeathers.

This custom arena incorporates a harmless mechanical gate to encourage bovine participation in the program.

EXERCISE FOR DAIRY COWS

ROBERT C. LAMB and MELVIN J. ANDERSON

During the past 30 years, dairying has undergone drastic changes. In Utah and other western states, many milking cows are kept in dry lots with no access to pastures. This has created a whole new lifestyle for dairy cows: confined to concrete surface corrals, housed in open sheds with bedding stalls, and milked in elevated milking parlors.

While this has generated many advantages for the dairyman, it has also created disadvantages for both the cow and the dairyman. Foot and leg problems seem to be more common. Breeding programs suffer because confined cows in large herds do not exhibit estrus as readily. Difficulty in calving and health problems after calving seem more prevalent than they did before.

During this same period, the productivity of dairy cows has increased dramatically as a result of genetic improvement and better feeding and management practices. High producing cows have a negative energy balance early in lactation because during that period they do not eat enough to supply the nutrients they require for milk production. Consequently, fat is taken from the cow's body and converted to energy. When the excess fat is gone, production declines until nutrient intake equals nutrients excreted in milk. Furthermore, this loss in weight coincides with the time for breeding and lowers fertility.

After brainstorming these problems and possible solutions, scientists from the U.S. Department of Agriculture and Utah State University started a cooperative study of the effects of exercising dairy cows during the two months prior to calving. The hypothesis was that cows had inadequate feed intakes during early lactation not because they had insufficient physical capacity (we had evidence from previous research that cows eat more later in lactation when they don't need as much), but because they lacked appetite. Such a phenomenon could be caused by the circulatory system not being able to take the necessary load of nutrients from the digestive system to the milk secreting cells in the udder. We know that athletes must train to build up physical capacity, horses need to

Table 1. Averages for calving and reproduction for heifers in Trial I.

Variables	Treatment[1] Control	Exercise
Edema evident[2]	18.9	14.9
Edema at calving[3]	2.1	2.0
Postpartum edema[4]	23.4	23.1
Calving ease[5]	2.1	1.4
Placenta release time[6]	4.2	2.5
Days to first estrus	53.6	53.6
Days to first service	63.5	75.2
Number of services	3.1	2.4
Days open	158.7	111.4

[1]Control = no exercise; exercise = 3.4 miles per hour for 1 mile per day for 4 weeks.
[2]Number days prepartum edema first evident.
[3]Severity of edema: 1 = minimum, 5 = maximum.
[4]Number days postpartum edema still evident.
[5]1 = easy calving to 5 = dystocia.
[6]Number of hours from calving to placenta release.

Table 2. Averages for reproduction and daily feed intake prior to calving for heifers on Trial II.

Variables	Treatment[1] Control	Exercise
Days to first estrus	49.4	37.8
Days to first service	59.2	61.6
Number of services	2.0	1.6
Days open	92.5	78.4
Hay intake (lb/day)	13.7	13.0
Silage intake (lb/day)	22.9	25.4
Grain intake (lb/day)	2.2	2.2
Digestible energy (Mcal/day)	26.2	26.4
Body weight change/day (lb)	1.4	1.3

[1]Control = no exercise; exercise = 2.2 miles per hour for 1 mile per day for 6 weeks.

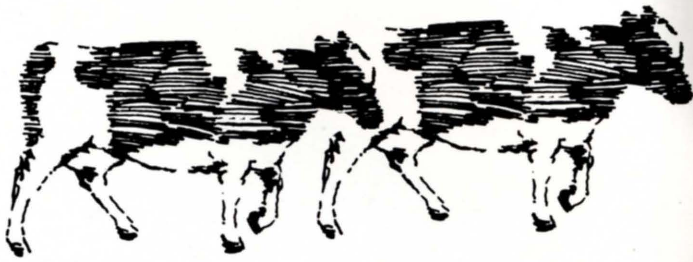


Table 3. Average feed intake, milk production, and milk composition for heifers in Trial I.

Variables	Treatment[1] Control	Prepartum	Postpartum
	First 50 days		
No. animals	14	14	12
Hay (lb/day)	16.3	14.8	15.7
Grain (lb/day)	20.7	20.3	19.4
Digestible energy (Mcal/day)	48.3	46.0	45.2
Milk yield daily (lb/day)	53.1	50.7	47.0
Feed efficiency (%)[2]	33.4	33.3	32.3
	305-day lactation		
No. days	295	298	285
Milk yield (lb)	12,963	12,405	11,389
Fat (%)	3.7	3.6	3.7
Protein (%)	3.3	3.4	3.3
Solids-not-fat (%)	8.5	8.6	8.4

[1]Control = no exercise; prepartum = exercise at 3.4 miles per hour for 1 mile per day for 4 weeks before calving; postpartum = same as prepartum but continued for 10 days after calving.
[2]Feed efficiency calculated as (.75 x fat-corrected-milk)/digestible energy.

exercise to build up the heart and lung capacity to race, and human beings have taken up jogging to strengthen hearts and circulatory systems. In contrast, cows are getting less exercise than ever before because of confinement.

An exerciser consisting of a circular lane about 3 feet wide and 100 feet in circumference was built at the USU Dairy Research Farm. A variable-speed electric motor powered four moving gates that drove the cows. These gates were hinged at the top so they would ride up over the backs of tired or reluctant cows without injuring them or damaging the equipment.

No reports of exercise for dairy cows could be found. We had no guidelines on how much exercise a cow might need or could sustain. We didn't know how fast or how far a cow could walk. Consequently, three trials were conducted, one with 81 cows that had completed one to five lactations and two involving 81 heifers prior to their first calving. Animals within each age group were divided into units and given various amounts of forced exercise for 4 to 8 weeks prior to calving. Exercise ranged from none for controls to one to six miles per day (5 days per week) at rates from 2.2 to 3.4 miles per hour for exercised animals. These speeds produced a slow leisurely gait up to a fast walk. No cows were forced to run.

Results with the two-year-old heifers were generally positive and beneficial (Tables 1-4). Exercise reduced the number of days before calving when edema in the udder became evident. However, it did not reduce the severity of edema or the duration of edema after calving. Exercise increased ease of calving and reduced the time from calving to release of the placenta (Table 1). Improved ease of calving is a very beneficial result because difficult calving, particularly with a first calf, has become increasingly prevalent as more dairy heifers are grown in confinement. Although results were not statistically significant, exercised heifers required fewer services for conception and had fewer days open than did unexercised control heifers (Tables 1, 2). We anticipated that exercise would increase feed intake or reduce body weight gain prior to calving because of the calories used in exercise. There was no difference in either parameter for heifers (Table 2), but older cows that were exercised did evidence a reduced weight gain (Table 5).

In the first trial with two-year-old heifers, exercise was continued for 10

Table 4. Average feed intake, milk production, and milk composition for heifers in Trial II.

Variables	Treatment[1] Control	Exercise
	First 50 days	
No. animals	18	23
Hay (lb/day)	10.1	11.0
Silage (lb/day)	22.0	22.5
Grain (lb/day)	16.3	17.0
Digestible energy (Mcal/day)	41.6	43.6
Milk production (lb/day)	43.9	50.3
Feed efficiency (%)[2]	35.5	38.8
	305-day lactation	
No. days	286	287
Milk production (lbs)	10,846	12,458
Fat (%)	3.7	3.5
Protein (%)	3.8	3.7
Solids-not-fat (%)	8.5	8.4

[1]Control = no exercise; exercise = 2.2 miles per hour for 1 mile per day for 6 weeks.
[2]Feed efficiency calculated as (.75 x fat-corrected-milk)/digestible energy.

Table 5. Average daily feed intake before calving and feed intake, milk yield, and milk composition for 70 days after calving for older cows.

Variables	Treatment[1] 1	2	3	4
No. cows	20	19	20	22
	Pre-calving period			
Hay (lb/day)	14.8	13.7	16.3	14.6
Silage (lb/day)	29.0	28.4	27.8	28.5
Grain (lb/day)	4.2	4.0	3.9	4.2
Dry matter (lb/day)	25.4	23.5	23.4	24.4
Body weight (lbs)	1692	1652	1658	1680
	After-calving period			
Hay (lb/day)	14.9	14.0	14.1	16.0
Silage (lb/day)	19.8	21.2	20.1	20.2
Grain (lb/day)	22.5	22.2	22.6	22.6
Digestible energy (Mcal/day)	54.6	53.6	53.9	56.2
Milk yield (lb/day)	67.1	68.3	68.6	67.2
Fat (%)	3.8	3.5	3.5	3.3
Protein (%)	3.4	3.3	3.3	3.3
Solids-not-fat (%)	8.4	8.3	8.2	8.1

[1]Treatments: 1 = no exercise; 2 = 2 miles per day at 2.2 miles per hour; 3 = 6 miles per day at 2.2 miles per hour; 4 = 2 miles per day at 3.4 miles per hour.

days after calving for some of the heifers. This proved detrimental (Table 3). Exercise after calving reduced intake of digestible energy and production of milk and shortened the lactation. In the second trial (Table 4), exercise restricted to a before-calving schedule resulted in increased feed intake and milk production during the subsequent lactation. The increase in milk production (approximately 3 quarts per cow per day) was greater than for feed intake, indicating an improved efficiency of converting feed to milk. Furthermore, the daily increase in production was maintained throughout the lactation. Exercise did not affect the fat, protein, or solids-not-fat percent composition of the milk.

With the older cows, exercise before calving had no influence on feed intake or production of milk after calving (Table 5).

Differences in exercise regimens may have been responsible for the divergent results among the three trials. Heifers in the second trial were exercised at a slower pace but for 2 to 3 weeks longer than heifers in Trial I. Older cows showed no benefit from exercise at either of the speeds used in the trials with heifers. The older cows, however, had been exercised for a minimum of 2 miles per day, while heifers went for 1 mile per day. Thus, distance may influence the effect of exercise. One additional factor to consider in comparing results between young and older cows is that young cows may be better able to benefit from exercise. It may be that cows, like humans, will benefit most from a sound exercise program throughout their lifetime.

ABOUT THE AUTHORS

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In 1980, 600 million pounds of U.S. cheese will be made using the

USU LACTIC CULTURE SYSTEM

G. H. RICHARDSON, G. L. HONG, and C. A. ERNSTROM

The Utah State University Lactic Culture System combines conventional bulk culture tanks, pH and temperature controllers, with diluted fresh liquid whey that contains stimulants and phosphates/citrates. The bacteria produced in this system are more numerous and more active than those commonly used. In addition, these bacteria can be stored for days, thus eliminating the need for daily lactic culture propagation. The new USU system provides the cheese industry with many economic advantages over conventional culture systems.

EQUIPMENT AND SUPPLIES

CULTURE TANK. Sealed culture tanks are best; however, they are not readily available in the United States. It is necessary, therefore, to atmospherically isolate tanks and incorporate citrates or phosphates in the media to minimize the effects of bacteriophage (phage) infection. The tank should provide slow speed agitation throughout the culture fermentation cycle, and it must be equipped with pH and temperature controllers.

pH ELECTRODE AND CONTROLLER. The Ingold[a] electrode has been used in the fermentation industry for years and has proven very reliable in the lactic culture industry. It can withstand steam sterilization pressures and temperatures and can be cleaned in place. A typical electrode has withstood over eight months of continuous daily culture preparation before being rejuvenated and replaced. The electrode is connected to a pH controller that records a pattern indicating culture growth and activity. Dialing systems can be placed upon the controller that will place telephone calls and notify plant personnel of equipment failure. Equipment and supplies are available from commercial sources.[b]

AMMONIA GAS AND VALVES. Refrigeration-grade anhydrous ammonia has specifications that exceed those required for Codex Alimentarius Food Grade ammonium hydroxide and therefore qualify for the Generally Recognized As Safe status of the Food and Drug Administration. (A food additive status could be sought if necessary.) The gas is available at most dairy plants and can be readily used to neutralize the acids formed during the culture fermentation. A pressure reduction and venting system should be attached to the gas tank. The gas then passes through stainless steel tubing to a three-way solenoid valve operated by the controller. The valve allows ammonia gas into the culture tank when activated. A 1'' or larger ID pipe conveys the gas below the culture medium surface where it immediately dissolves in the medium and neutralizes excess acid. The large diameter pipe eases cleaning and inspections. When inactivated, the valve restores atmospheric pressure in the tubing to prevent the culture from backing up into the ammonia lines and valving.

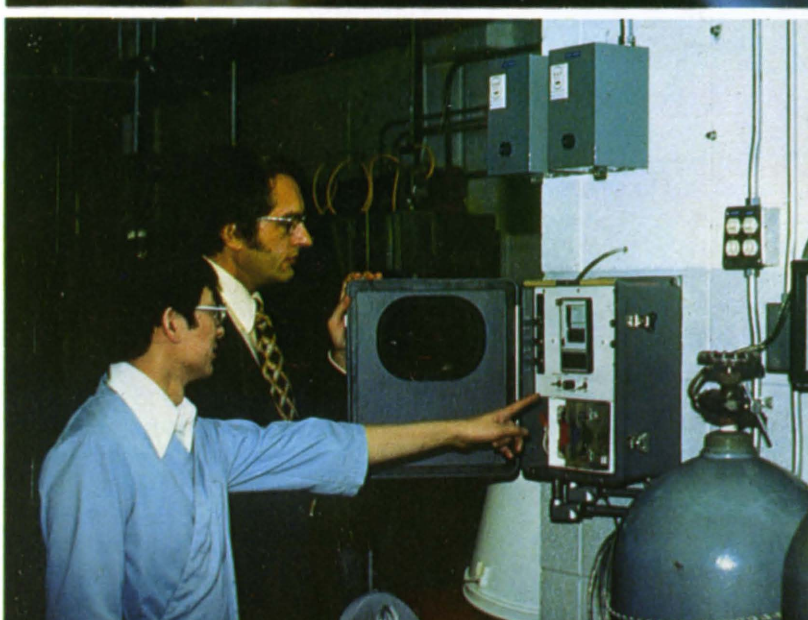
TEMPERATURE CONTROLLER. The streptococcal cultures used for American and cottage cheese production are propagated at 27 C. Ammonia gas generates heat when injected and causes the culture temperature to rise. It is thus necessary to incorporate a temperature sensor into the culture tank and include an automatic water control valve in the tank cooling system. Whenever the temperature increases, the valve is opened and the culture is automatically cooled to 27 C. The organisms used in Swiss and Italian cheese production need control at higher temperatures.

MEDIUM. Fresh liquid whey is the most readily available and economical source of energy for the propagation of lactic cultures at the cheese factory. Phosphates and some nitrogenous materials are necessary adjuncts to make the medium inhibitory to phage development while providing maximum stimulation for the cultures. The whey must be diluted with water to reduce lactose levels in the medium. This is because *all* the sugar is fermented to lactate ion during the cycle and this ion is toxic to the cells. Diluting the lactose helps ensure a maximum growth of cells without any buildup of toxic end products.

CULTURES. Any source of lactic cultures that has proven workable to inoculate bulk cultures in the cheese plant will work with the USU Lactic Culture System. Improved cheese quality has been reported through the use of identified pairs or blends of single strains of streptococci.

Slabs of curd cheese are moved along in a Cache Valley cheese plant production line.

Photo by Carol Grundmann



Richardson and Hong take readings from pH recorder on a commercial cheese factory culture tank.

This sealed culture tank is still not readily available in the U.S., however, custom-made additions to existing tanks which seal and equip them for the procedure can be effective.

Photos by Gary Richardson

MOST FREQUENTLY ASKED QUESTIONS CONCERNING THIS SYSTEM

WHAT ARE THE GENERAL ADVANTAGES?

•Lower costs than are associated with conventional phage inhibitory media systems.
•Greater culture activity and end product uniformity.
•Bulk cultures don't need to be prepared daily or over weekends.
•Standby cultures can be held to back up the blend in daily use. Fewer blends can be employed with less concern for phage buildup.
•Cultures don't need the ripening periods in the vats which have been characteristic of frozen directly set programs.
•There are more bacteria per volume of medium.
•The culture never sours.
•No phosphates are required in protected equipment. Lower phosphates are required in unprotected equipment, thus cultures are more active. Also, there is less adverse effect upon the calcium chloride added to milk for curd firmness improvement.
•Cultures have less pH adjustment lag than conventional "sour" cultures when added to the cheese milk vats.
•Ingredients are instantly soluble.
•Energy nutrient source (lactose) is readily available and economical. It doesn't have to be condensed, dried, and shipped from other areas at great expense.

WHAT ARE SOME SPECIFIC ECONOMIC ADVANTAGES?

There are advantages for cheese plants of all sizes to consider. Plants producing only 6,000 pounds per day estimate savings $16,000 per year. Plants now on the program save from $100,000 to $250,000 per year over the costs associated with conventional phage inhibitory media programs. The capital equipment costs can be recovered in a few weeks or days.

ARE YIELDS LOWER?

Yes, yields are lower than when casein is present in the medium. It is true that there is no casein in the whey medium to produce cheese, though the whey protein yield value is unchanged. Heated casein is not the best cheese yielding substance, therefore it is suggested that the casein be put into the cheese vat, unheated, for maximum yield advantage. This would allow the culture tank to produce active bacteria—not cheese.

HOW CAN CULTURES PERFORM NORMALLY WHEN THERE IS NO CASEIN IN THEIR ENVIRONMENT?

Hydrolyzed casein or whey protein is included in the stimulatory nitrogenous material in the medium. Cultures propagated in this medium have performed better in the vat due to the pH being closer to that of the milk and there being a greater number of cells. No ripening interval is needed before rennet addition. Cheese held during extended curing has been normal in every respect.

WHY IS THE CULTURE MORE ACTIVE AND LESS IS NEEDED?

Because there are 2 to 5 times the numbers of active cells per volume than with conventional cultures. They are more active because they do not have to adjust to as great a pH shock when added to cheese milk. They go from pH 6 to pH 6.6 instead of from pH 4.7 to pH 6.6. They also go to the same predictable endpoint each day due to the limited lactose. In contrast, conventional cultures are "somewhere along the way" at the time they are used.

WHAT IS THE NORMAL CULTURE-CYCLE TIME?

Cultures will vary depending upon the inocula volumes used and the strains involved. However, cultures incubated at 27 C can be ready to use in 10 to 20 hours. Remarkable stability allows them to be held without cooling. A 27 C culture thus can be used for over 24 hours without activity change.

HOW ABOUT IN-PLANT PHAGE CONTAMINATION?

No phage can survive the 90 C for 45 minute temperature treatment given the medium prior to cooling and inoculation. The phage would be just as "dead" as if it came into the plant via dry whey powder which had been processed in another plant thousands of miles away.

WHY ARE THESE CULTURES MORE STABLE DURING STORAGE?

The lactose is all used up and the bacteria have no way to produce more acid during storage. The storage pH thus remains near 6 and the adverse effects associated with high acidity are avoided. The pH controlled cultures have kept normal activity during refrigerated storage for 40 days depending upon the blend of strains in the culture.

Cultures may be held at 4 to 13 C for at least a week as reserve culture in the event of phage buildup against the culture in daily use. The culture can be used even after considerable activity loss—though at higher inocula levels.

BUT WHAT ABOUT THE INHIBITORY SUBSTANCES THAT SOME STRAINS PRODUCE IN WHEY THAT COULD AFFECT SUBSEQUENT LACTIC ORGANISMS GROWING IN THE WHEY?

Most mixtures of the lactic strains used in cheese production prove stimulatory when grown together. This stimulation occurs when the strains follow each other in the same medium just as it does when they grow side by side.

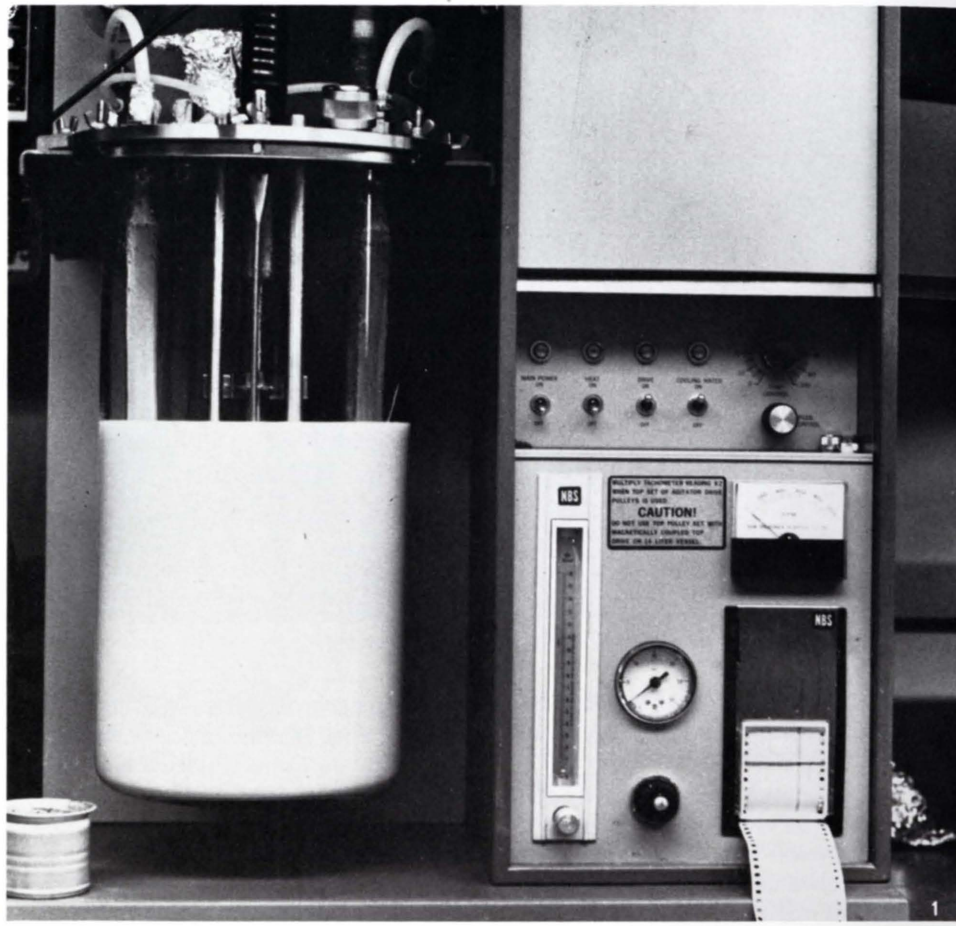
WHEN pH CONTROL IS USED, ISN'T THERE MORE POTENTIAL FOR THE GROWTH OF CONTAMINATING ORGANISMS?

Contaminants don't compete well with lactic organisms that are propagated with or without pH control. The lactic streptococci have better activity under pH control. Staphylococcus organisms inoculated into the pH controlled cultures were unable to grow or produce toxin when active lactics were present. Coliforms and perhaps some other organisms can grow in competition with lactic streptococci. However, the numbers of contaminants would generally be low compared to the billions of active lactics added at inoculation. Several plate count surveys have produced data to confirm that there is in practice less of a problem with contaminants in the pH control system than with conventional bulk cultures. This is probably due to the "healthier" lactic organisms. Phage contamination is a more likely problem.

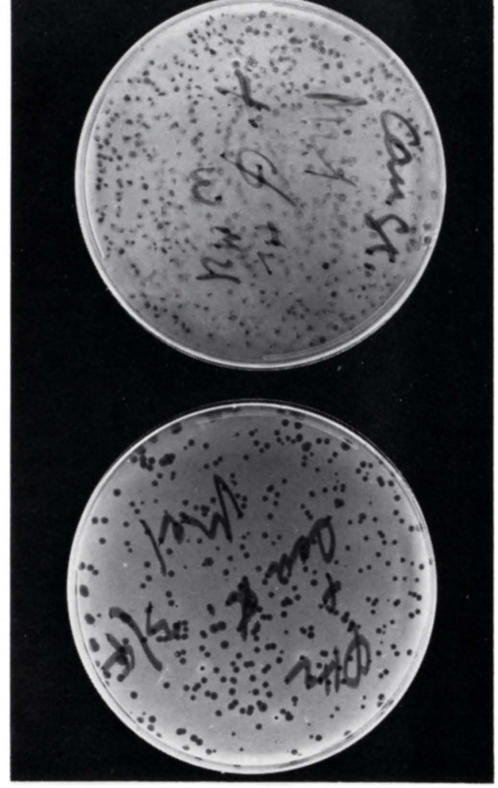
PROCEDURE

1. Pump sufficient fresh liquid whey and water into the bulk culture tank to result in a 3.75% lactose solution and commence agitation.
2. Add ten pounds of phosphate/stimulant blend per hundred gallons of medium. Be sure the mixture is above pH 6.2 through ammonia injection if necessary.
3. Standardize the pH control system following warmup by noting the pH reading on the medium. Withdraw a sample, check the pH of the medium on a laboratory meter and adjust the controller reading accordingly. Then turn off the controller until the heating-cooling cycle is over.
4. Heat the entire bulk culture tank contents to 90 C and hold for 45 minutes.
5. Cool the medium to 27 C and inoculate the culture through a steam ring or similar protective inoculation system.
6. Activate the pH control system. The phosphates in the system provide buffering, which can be used to check operation of the pH instrumentation at startup. Set pH controls at 6 and allow sawtooth trace development from 6 to 6.2 on the chart. Set high and low alarms at pH 7 and pH 5.8, respectively.
7. The culture cycle should be complete in 14-20 hours. It can then be used without cooling throughout the day or cooled and pumped into storage tanks for subsequent utilization.
8. Inoculate cheese milk at 10 to 40% of normal volumes depending upon previous history of the culture in the plant.

USU produces the concentrated bacteria in the fermentation above (1) and places each sample in a sterile number container (2) in which it is distributed. The pH electrode transmits a signal record of the pH on strip chart recorder.



Mike Jackson



LEFT: Lawns of lactic cultures propagated on nutrient-agar media in petri dishes. The clear zones are where bacteriophage have dissolved the lactic culture cells.

RIGHT: A scanning electron micrograph of commercial yogurt. The long rods at the left are lactobacilli. The spherical bacteria in the center are streptococci. Both microorganisms grow well in the USU lactic culture system. The surrounding structure is the coagulum, composed primarily of destabilized milk protein (casein) micelles. Magnification 6,000x

DOESN'T STRAIN DOMINATION OCCUR MORE RAPIDLY WHEN pH CONTROL IS USED?

Yes. The pH control shortens bacterial generation times and produces more cells in less time. Thus, if dominance is likely in a conventional blend due to an imbalance of strains at inoculation, it is likely to occur earlier. This potential can be minimized through inoculating single strains in known proportions.

WHAT HAPPENS IF THE SYSTEM FAILS?

Alarms are built into the control equipment. For the first time in history, plants have a means of knowing culture activity and an indication of inadequate growth through the recorder tracing. If the ammonia valve sticks and too much gas gets into the tank a dead culture will result and back up blends must be used. If the ammonia feed system fails, the pH will drop to normal levels and the culture will have the same activity characteristics as a conventional culture and can be used accordingly. The reliability of the currently available electronic pH equipment is such that very few failures have been encountered. The overall benefits far outweigh the possibility of problems through equipment failures.

CAN THE SYSTEM BE USED FOR ALL TYPES OF CHEESE?

Over nine years of plant field experience has involved the manufacture of American style cheeses. The system has also been successfully used in cottage cheese production for more than one year, where inocula levels of 2% produce normal, short-set cutting times. There has been over six months plant experience using the system for Swiss cheese production, and inocula levels have been one-tenth that of normal requirements. One culture tank inoculates 120 vats instead of 13.

Only the high temperature cocci have been so propagated in the factory. Laboratory work at USU, however, has demonstrated that the rods also perform satisfactorily under pH control. Their balance would have to be monitored carefully if propagated together. Though there has been no plant experience with Italian cheese there is a greater economic potential here because of the higher levels of starter used. The pH control system has little to offer sour cream, buttermilk, yogurt, or cream cheese production.

DON'T WHEY-TAINT OR OTHER OFF-FLAVOR PROBLEMS DEVELOP IN ANY CHEESE VARIETIES?

No off flavors were noted even when 5% culture was used in cottage cheese. In American style cheese we are in effect adding .4 to 1.0% spent lactose whey to 90% whey by-product from the manufacture. No flavor problems have been reported and tons of cheese are made daily. Whey solids are now used in many of the inhibitory media on the market with no flavor defects. Fresh whey should have fewer potential flavor problems than processed whey.

ARE SCIENTIFICALLY TRAINED PERSONNEL NEEDED IN THE PLANT BEFORE TRYING THIS SYSTEM?

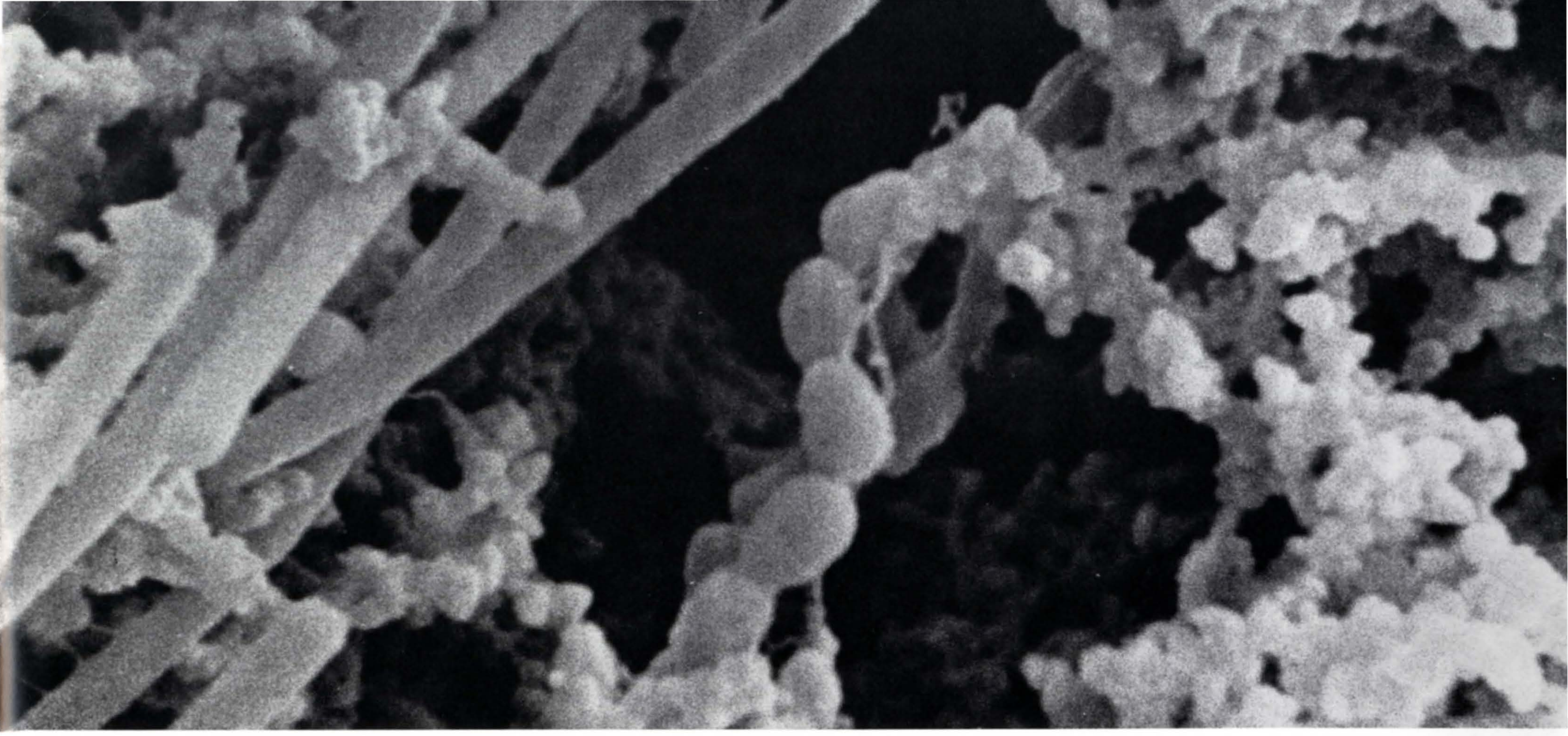
Many of the units now in the field are operated in small plants by personnel with minimal training. The system requires no more technical ability than other operations associated with cheese making.

CAN THE SAME INOCULATION BE USED FOR VAT AFTER VAT?

Any culture system requires adjustment of the inocula volume depending upon the activity of the strains involved. This has, however, made that volume more uniform and the final product acidity more uniform.

WHAT ARE THE ADVANTAGES OF HAVING A LOWER PHOSPHATE CONTENT WITH THE SYSTM?

Calcium is dissolved as acid develops in a conventional culture. The calcium is released from insoluble salts. High phosphate levels are required in conventional phage inhibitory media to keep the calcium low and therefore prevent the phage from attaching to the bacterial cell wall. When the pH is controlled, less calcium is released, therefore only one-third the usual amount of phosphate is needed to provide the same protection. There is also less calcium in the whey than in milk-based media. Calcium chloride can legally be added to cheese milk and can



Courtesy of Dr. M. Kalab, Food Research Institute, Ottawa, Ontario, Canada.

have a greater effect upon curd quality when fewer phosphates are added via the culture. Milk coagulation also occurs more rapidly with fewer phosphates.

WITH ALL THOSE STIMULANTS IN THE MEDIUM, HOW DO THE CULTURES PERFORM WHEN TRANSFERRED TO MILK?

Great! (All special culture media on the market for the past 15 to 20 years contain stimulants.)

WHY USE THE PARTICULAR STIMULANT BLEND DESCRIBED?

Any culture medium including milk will produce more active culture when under pH control. It is a matter of efficiency, predictable culture activity and storage stability. We feed poultry and animals blends of feeds to assure maximum growth and production. Why not give bacteria the same opportunity? The culture medium recommended has been formulated during ten years of research and using computer-coupled projects. Phosphates are suggested for phage protection only if bulk culture tanks are open to the atmosphere.

DON'T ATMOSPHERIC EXPOSURE AND AGITATION RESULT IN A TOXIC OXIDATION REDUCTION POTENTIAL?

Yes. Aeration produces toxic substances in lactic cultures that will inhibit culture growth and acid production. This is overcome through incorporating some minerals and yeast extract into the medium, by using slow speed agitation and filling the bulk tank to its maximum. Another alternative would be the use of bulk tanks that could be partially sealed during fermentation.

WHAT ARE THE TYPICAL USAGE LEVELS FOR THE INGREDIENTS IN THE SYSTEM?

The fresh liquid whey would be diluted to about 3.5 to 4% lactose. The phosphate stimulant blend would be added at about 1.2% and the amount of ammonia used for a cycle would amount to approximately 1.1%.

WHY ADVOCATE ANHYDROUS AMMONIA GAS INSTEAD OF AMMONIUM HYDROXIDE, CAUSTIC SODA OR SOME OTHER NEUTRALIZER?

Ammonia is less toxic to the cells than some other neutralizing substances. It is readily available, easy to handle at the plant and can be obtained in large storage tank quantities. A solution of ammonia (ammonium hydroxide) would prevent the need for the temperature controller on the culture tank but would require the handling of an additional product at the plant. Sodium hydroxide is more difficult to handle, and sodium ions are much more toxic to the bacterial cells than ammonium ions.

[a]Mention of products or companies does not constitute an endorsement by Utah State University over products of a similar nature not mentioned.

[b]Biolac Inc., 745 East 50 North, Logan, UT 84321, (801) 752-6820

The statements made in this report are supported by over ten years of research by the Utah Agricultural Experiment Station at USU, the New Zealand Dairy Research Institute, and in cooperating cheese plants and industry laboratories. Reprints of reports containing the scientific data are available upon request. Please write to:

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ABOUT THE AUTHORS

Gary H. Richardson, Professor of Food Science and Food Microbiology in the Department of Nutrition and Food Sciences, conducts research in dairy instrumentation and cheese processes. He also teaches courses in food analysis, food fermentation, and food inspections and regulations. Professor Richardson was the 1978 recipient of the Pfizer award for research in cheese and cultured dairy products which is awarded annually by the American Dairy Science Association.

G. L. Hong is a Research Associate in the Department of Nutrition and Food Sciences. He is currently completing his PhD.

C. A. Ernstrom is Professor and Department Head, Department of Nutrition and Food Sciences. His current research interests include cheese manufacture, the chemistry of milk and cheese, milk clotting enzymes and ultra-filtration of milk for cheese-making.

The purple tradescantia (TOP INSET) as it appears in nature.

A tradescantia (BOTTOM INSET) after being grown on tailings from a uranium millsite, is physically distorted.

The Vitro plant tower, Salt Lake City, looms up behind vials of processed uranium ore (yellowcake).

W. F. CAMPBELL and E. A. RECHEL

TRADESCANTIA

A "SUPER-SNOOPER" OF RADIOACTIVITY FROM URANIUM MILL WASTES

The use of nuclear power as an energy resource is being debated nationally and internationally as the technology to fully exploit nuclear power on a large scale is rapidly becoming available. In 1976, the outcome of the presidential election in Sweden was determined by each candidate's stand on nuclear power. Major opposition to nuclear reactors as a source of energy has surfaced in Great Britain, and the United States' role as a supplier of nuclear energy has been critically questioned.

Nuclear power can undeniably answer many of the world's energy needs and lessen dependency on petroleum and natural gas—but only in conjunction with ominous unknowns: How do we dispose of the rising flood of radioactive waste? Are lands on which radioactive wastes are stored, committed to this use eternally? When nuclear power or processing plants are closed, who is responsible for the radioactive remains? Can the land involved with such nuclear facilities be recycled? Do radioactive sites pose health hazards to adjacent plant and animal (including human) communities? Do we have non-mechanical alternatives for adequately monitoring nuclear plant sites or mill wastes for their chronically emitted amounts of low-level ionizing radiation?

At present, nearly 5,200 tons of spent fuel from 72 U.S. reactors are temporarily stockpiled. By 1990, the amount is expected to rise to 37,900 tons. In addition to the spent-fuel residues, uranium mill tailings constitute a large and evergrowing problem. Besides the 27 million tons of tailings found at inactive sites such as the one in Salt Lake City, another 113 million tons have accumulated at sites where uranium is currently being milled. Given the rapid pace at which the uranium industry is now expanding to meet its contracts with electric utilities, this could increase to a billion tons by the year 2000.

The Vitro Chemical Company in Salt Lake City, now defunct, processed uranium ore to produce ^{308}U or "yellowcake" for the Atomic Energy Commission (AEC) and U.S. Military programs from 1953 to 1967. During its operation, the plant deposited mounds and ridges of tailings over 45 hectares (112 acres) of adjoining land. That land is now in the middle of a metropolitan area of more than a half million people, who are being unwillingly exposed to radioactive dust, radon gas, decay products of radon gas, and gamma radiation.

The greatest hazard from mill tailings is associated with radon-222, a short-lived daughter of radium-226. The radium-226 is found near the end of a chain of long-lived radionuclides that begins with uranium (half-life, 4.5 billion years) and its daughter thorium-230 (half-life, 80,000 years). Unless covered with thick (several feet) layers of clay and other material, an abandoned tailings pile may exhale radon gas for many years at up to 500 times the natural background rate. Radon's daughter-products cause lung cancer and are responsible for the notoriously high incidence of this disease among uranium miners. This radioactivity may contaminate surrounding terrestrial and aquatic communities.

Additionally, any plant species considered for rehabilitating radioactive mill tailings must be able to survive the radioactivity. Apart from possible reductions in plant growth and yield, genetic alterations are of considerable concern to plant scientists.

Radiation/Plant Interactions

Scientists in the Plant Science Department at Utah State University decided to check how low levels of ionizing radiation emitted from tailings might affect mutation frequency, reproductive integrity, and pollen viability of selected plants. Moreover, they wanted to determine if selected plants could be grown on the radioactive waste areas or near nuclear reactor spoils to monitor the amount of radiation being emitted.

To assess its monitoring potential, a plant of known radio-sensitivity, *Tradescantia*, clone 02, (obtained from A. H. Sparrow, Brookhaven National Laboratory) was grown in radioactive soil taken from five sites on the Vitro Chemical Plant's mill tailings (located at 3300 South, 900 West, Salt Lake City, Utah). The samples had radioactivity levels of 1.11, 1.62, 2.04, 2.72, and 3.32 mR/hr, respectively. The activity of samples taken from a control site (i.e. not near the mill) were 0.01 mR/hr. After transporting the tailings from the Vitro mill area to the greenhouse at Utah State University, the amounts of ionizing radiation were 0.07,0.10, 0.14, 0.20, and 0.19 mR/hr, respectively, with the control remaining at 0.01 mR/hr. The differences were considered due to the absence of the overall Vitro radiation field.

Tradescantia, clone 02, is a perennial, herbaceous plant with narrow tapering leaves, not unlike some of the medium-size grasses, and it reaches a height of about 60 cm (24 inches). It is heterozygous for blue and pink flower color and is considered to be a hybrid between *T. occidentalis* and *T. ohiensis*. Genetic variability is minimized in clone 02, since experimental plants are easily propagated by cuttings.

Clone 02 plants are extremely sensitive to chemical mutagens,* and ultraviolet or ionizing radiation. They nevertheless can survive in test environments for long periods of time, thus acting as mutagen monitors. When used in this way, periodic checking of the heterozygous flower petals or stamen hairs for somatic mutations is the method used to decide whether environmental agents are causing mutations, and, if so, to what extent. When used over short time periods, the *Tradescantia*, clone 02, test system still produces adequate cell populations for statistical analysis. In either time frame, the radio-biological data from the stamen hairs, e.g., mutation rate and reproductive integrity, can be compared with similar data from micro-organisms and mammalian cell cultures. Maintenance of the plants and the scoring of the different radiation-induced changes are easily and quickly accomplished.

Tradescantia plants of equal size and containing young inflorescences were selected from a stock population. Root systems were washed in water to remove soil. Repotting was in either radioactive tailings from one of the five sites or control soil. Plants were grown under greenhouse conditions with a 16-hour light cycle, a day temperature of 35 C, and night temperature of 20 C. The pH of all radioactive tailings was adjusted to that of the control soil (pH 8.0) with $CaCO_3$. A nutrient solution was added to each pot once every five days through the first two weeks. Plants at each radiation level were separated by 30 cm on the same greenhouse bench and those in the control soil were located in an adjacent room.

Ten days after the plants had been potted, data were collected for 20 continuous days on the number of stunted hairs, somatic mutations per stamen, and percent pollen viability. The 10-day lag period: 1) allowed the plants to recover from the shock of transplanting, and 2) was the usual time needed for effects of radiation treatment to become visible.

Flowers were chosen randomly from each treatment group, each day, and from each of these flowers, stamens were chosen at random for scoring. The types of somatic aberrations scored were blue to pink, blue to colorless, colorless to pink, normal size cell to giant or dwarf, and branched hairs. Loss of reproductive integrity in stamen hairs was measured by the number of stunted hairs. An average hair from a healthy plant consists of 20.5 cells; a stunted hair has been defined as one with 12 cells or less. Pollen viability was determined by randomly selecting flowers from among those previously picked and smearing the anthers on a slide to release the pollen grains. The pollen was then stained with acetocarmine. Viable pollen absorbs this stain and the nucleus appears red; aborted pollen remains yellow.

Results and Implications

Statistical comparisons of the average number of mutations per stamen for each level of radiation are shown in Table 1. A linear regression analysis with adjusted treatment means demonstrated a significant correlation ($r = 0.78$ and $r^2 = 0.62$) between radiation level and number of mutations per stamen were observed with radiation level as low as 0.10 mR/hr when compared to those of the control. A linear regression, using adjusted means, indicated a significant correlation ($r = 0.88$ and $r^2 = 0.77$) between radiation level and number of stunted hairs per stamen (Table 2).

Pollen viability ratings, averaged for each radioactive soil level, are shown in Table 3. Statistical comparisons showed significant differences between the different radiation levels. However, the linear regression of radiation level versus pollen viability was not significant.

These data from the *Tradescantia* stamen hairs and pollen suggest that plant species would have to adjust to an increase in somatic mutations and a decrease in reproductive integrity and pollen viability when growing on radioactive mill tailings such as from the Vitro Chemical Plant.

The levels of radiation measured in the greenhouse were considerably lower than those recorded on the mill tailings. If it had been possible to grow and tend these plants on the site, the differences between the radiation-level plants and the controls might have been more pronounced.

Ore for the Vitro Chemical Plant and its milling operations came from numerous mines that provided different mineral types. This, combined with a 1956 change in the procedure for extracting the uranium, means that soil texture and chemical makeup vary from one site to another. The presence and availability of numerous radionuclides are further modified by differential leaching of soil types. Consequently, total radioactivity and the degree to which given radionuclides are available to plants differ among sites.

Although the radiation levels from the tailings of the Vitro Chemical Plant caused detrimental effects in *Tradescantia* stamen hairs, one must realize that not all plant species exhibit this degree of radiosensitivity. Also, stamen hairs may be more sensitive to radiation than the rest of the plant. Many other physiological and morphological attributes of a species are relevant to whether it can exist in an environment subjected to above normal radiation levels, e.g., nutritional state, growth hormone concentrations, plant size, root depth, time required for mitosis and meiosis, percentage of cells dividing in the meristem, and interphase chromosome volume.

Radioactive uranium mill tailings, however, are potentially hazardous for any colonizing plant species. If a species has any mechanism that imparts a relatively high radioresistance, it will tolerate the average tailing radiation. Susceptible plants may evidence a lower fecundity, a higher somatic mutation rate, and a decrease in reproductive integrity. If all three

*agents which cause genetic mutation.

occur in a plant species, its competitive ability relative to radioactive sites will be low. Only the more radioresistant species can colonize such sites. Natural, long-term succession on radioactive uranium mill tailings or spent nuclear fuel wastes sites, therefore, may not proceed in the same direction or at the same rate as it would on a similar area lacking radiation stress. Revegetating programs must take this into consideration.

Uranium mill tailings and spent fuel wastes not only increase the radiation stress experienced by the flora and fauna inhabiting the site, but also that of surrounding biological systems. Examples from aquatic communities are the Jordan River, as it passes near the Vitro Chemical Plant, the Animas River, as it flows past an old uranium mill in Durango, Colorado, and the San Miguel River in Western Colorado.

The effects of low-level chronic radiation on adjacent terrestrial communities need investigation. These communities may be exposed to: 1) radioactive dust, 2) water that has drained through uranium mill tailings and been contaminated with radionuclides, and 3) radioactive radon gas escaping from the mill tailings. Additionally, crops that are irrigated with contaminated water may undergo abnormal growth and development. Ramifications for human populations may include effects from culinary and irrigation water contaminated with radionuclides and/or from radioactive dust and radon gas in the air. Radionuclides present in crop and/or animal products may pose a health hazard.

All such possibilities should be considered and defined for specific circumstances.

ABOUT THE AUTHORS

William F. Campbell is Professor of Agronomy with the Plant Science Department, Utah State University. Dr. Campbell's training has been in Agronomy, Plant Physiology, Radiation Botany, and Cytology, with extensive experience in Electron Microscopy. His research interests include cytochemical, physiological, and ultrastructural responses of plants to environmental stresses.

Eric A. Rechel obtained his BS in Natural History in 1974 at Fort Lewis College in Durango, Colorado. He received his MS in 1977 at Utah State University, and is presently working with Dr. Michael Walsh in the Biology Department, USU, towards a PhD. He is studying the anatomy of the haustoria in parasitic flowering plants.

Table 1. Analysis of variance for statistical comparisons between the six treatment levels for the average number of mutations per stamen, and ANOV regression.

ANOV	d.f.	S.S.	M.S.	$F_{(cal)}$
Treatments	5	444.7	88.9	4.6**
0.01 vs 0.07 (mR/hr)	1	18.6	18.6	0.9
0.07 vs 0.10 (mR/hr)	1	1.9	1.9	0.1
0.01 vs 0.10 (mR/hr)	1	59.5	59.5	3.1*
0.14 vs 0.19 (mR/hr)	1	35.9	35.9	1.8
0.01-0.07 vs 0.10-0.14-0.20 (mR/hr)	1	93.6	93.6	4.8**
0.01-0.07-0.10-0.14-0.20 vs 0.19 (mR/hr)	1	195.0	195.0	10.0**
Residual	338	6557.4	19.4	
Corrected Total	343	7001.9		

ANOV (regression)	d.f.	S.S.	M.S.	$F_{(cal)}$
Model	1	3.2	3.2	6.5*
Residual	4	1.9	0.5	
Corrected Total	5	5.1		

MODEL Y = (10.86) (X) + 1.50

*Significant at the 90 percent confidence level
**Significant at the 95 percent confidence level

Table 2. Analysis of variance for statistical comparisons between the six treatment levels for the average number of stunted hairs per stamen, and ANOV regression.

ANOV	d.f.	S.S.	M.S.	$F_{(cal)}$
Treatments	5	101.6	20.3	2.8*
0.01 vs 0.07 (mR/hr)	1	9.5	9.5	1.3
0.07 vs 0.10 (mR/hr)	1	50.2	50.2	6.8*
0.01 vs 0.14 (mR/hr)	1	18.6	18.6	2.5
0.01-0.07-0.14 vs 0.10-0.20 (mR/hr)	1	53.7	53.7	7.4*
0.01-0.20 vs 0.19 (mR/hr)	1	1.7	1.7	0.2
Residual	338	2467.4	7.3	
Corrected Total	343	2569.0		

ANOV (regression)	d.f.	S.S.	M.S.	$F_{(cal)}$
Model	1	1.08	1.08	13.7*
Residual	4	0.32	0.08	
Corrected Total	5	1.39		

MODEL Y = (6.36) (X) + 1.36

*Significant at the 95 percent confidence level

Table 3. Analysis of variance for statistical comparisons between the six treatment levels for the average percent pollen viability, and ANOV regression.

ANOV	d.f.	S.S.	M.S.	$F_{(cal)}$
Treatments	5	27828	5565	15.0**
0.01 vs 0.07 (mR/hr)	1	293	293	0.8
0.07 vs 0.20 (mR/hr)	1	1030	1030	2.9*
0.07 vs 0.14 (mR/hr)	1	2076	2076	5.8**
0.10-0.19 vs 0.14-0.20 (mR/hr)	1	5520	5520	15.4**
0.14-0.20 vs 0.19 (mR/hr)	1	5560	5560	15.5**
Residual	200	71600	358	
Corrected Total	205	99428		

ANOV (regression)	d.f.	S.S.	M.S.	$F_{(cal)}$
Model	1	314	314	3.7
Residual	4	336	84	
Corrected Total	5	650		

*Significant at the 90 percent confidence level
**Significant at the 95 percent confidence level

UTAH TURKEYS
A TEAM PRODUCTION

DONALD C. DOBSON

Once upon a time, raising turkeys in Utah was a backyard industry. Gradually, as in the rest of agriculture, growers had to become more specialized if they wanted to sell their birds in the competitive national market.

Right now, commercial turkey production in Utah takes place almost totally within Sanpete and Sevier counties. The geographical concentration began around 1935 when farmers in the area recognized the need to specialize in an enterprise suited to their limited natural resources. Turkeys, with their ability to survive on any kind of soil seemed a likely possibility. Coupled to imaginative, aggressive management, turkey growing lived up to the farmers' hopes. By relying on organized cooperation, the growers gained access to such high cost, but essential, tools of modern turkey production as proven breeding stock, feed manufacturing facilities, slaughtering/packaging plant, and marketing channels.

The Utah turkey growers' major cooperative organization, the Moroni Feed Company, is one of the strongest farmers' cooperatives in the United States. It can claim credit for the survival of the "small" turkey producer in Utah despite a variety of economic obstacles. The Moroni Feed Company makes it possible for growers to raise 15,000 to 25,000 birds right along with individuals who have 100,000. In other areas of the United States, production units with fewer than a million birds are increasingly rare.

The Birds

Most of Utah's birds are of the white-feathered type that scientists first created during the 1940s. Initially these birds were small and inefficient. But they *were* early maturing. This quality gave them desirable marketing qualities and earned them years of continued breeding/testing work. Eventually the researchers managed to optimize the white turkey's good qualities, minimize their shortcomings, and thereby make them exceedingly popular.

In fact, throughout the U.S., turkey production is almost totally devoted to the whites. About 10 percent of Utah's production, however, is still of bronze turkeys, which track back to North America's original wild turkey. The Utah growers of bronze birds incidentally help satisfy the demand for bronze feathers by those who do fly tying and industries that use feathers.

Whatever the color of their birds, the turkey growers must make substantial outlays of money each year to stay in business. A 100,000-bird operation requires about $700,000 for production costs. Another $300,000 goes for processing and shipping.

Feed is the biggest single cost item in the production phase, accounting for approximately 65 percent of the total. About 150,000 tons (mostly grains and soybeans) are needed each year by Utah's turkey growers. Only five percent of this tonnage is produced in the state. Such reliance on imported feeds makes Utah's turkey industry hazardously speculative.

Of the approximately three million turkeys produced each year in Utah, only 20 to 25 percent are consumed in the state. The heavy (28 pounds and over) birds are sold almost exclusively to eastern markets such as restaurant chains that pay premium prices for the big birds. The lighter weight birds (both hens and toms) are marketed on the west coast and in the intermountain west.

Most Utah turkeys are marketed through Norbest Inc., a national turkey marketing cooperative. This method of marketing removes some of the risks inherent in selling perishable products.

Production Research

An especially remarkable aspect of the industry started in 1947, when the Utah Turkey Growers Association voted to collect funds from members to promote the welfare of the turkey industry on both local and national levels. A portion of each year's collection has always routinely gone to support research, mostly by USU personnel into problems the growers designate as being of special concern. This awareness of what research can do, and quickness to apply useful results have helped Utah turkey growers survive in an exceedingly competitive business.

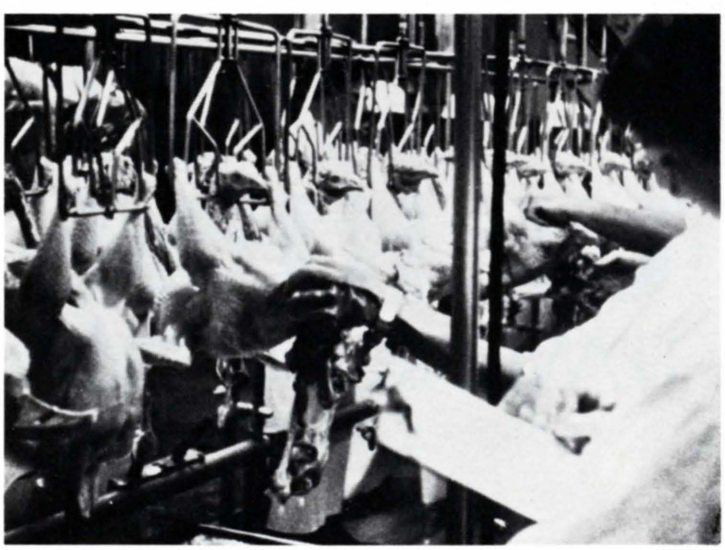
The results of USU's first poultry experiments (some of the earliest poultry research in the U.S.) were published in 1897. By the 1930s, as turkey growing in Utah was starting to evolve into a commercial enterprise, rations developed at USU were insuring efficient growth of the birds under Utah's stressful climatic conditions. Because turkeys are super-susceptible to weather-imposed traumas, much of the past *and* present research is concerned with these production factors. As always, however, as one problem is solved, others forge into prominence.

Today's disease-oriented research is concentrating on respiratory ailments, synovitis, skeletal problems, and brooder-house diseases.

To facilitate the growers' adapting to the 1960s revolution in the production and marketing of turkeys (larger flocks, selling parts of as well as whole birds, and new feeding procedures), Utah State University, in cooperation with Snow College, the Moroni Feed Company, and the turkey growers, established a turkey research project at Snow Field Station in Ephraim, Utah. The research project formalized the longstanding cooperation between the industry, the university, and the turkey industry. This unique arrangement has been used as a model elsewhere in the nation for agricultural research.

Research conducted under the cooperative agreement led to feeding programs that vary with the changing nutrient needs of the growing turkey. Turkeys throughout the intermountain west are now fed this way. The cooperative efforts at Ephraim also produced a program whereby commercial strains of turkeys are continually being evaluated from the egg stage through yields of meat in the processing plant.

Most Utah turkeys are still grown on open ranges with minimal if any housing. Considerable research is done at Ephraim to find ways to limit their susceptibility to Utah's climatic con-



ditions since, even if shelters are provided, birds may not use them, and/or may pile upon one another and suffocate. Unsupervised shelters are not a solution.

Product Research

Modern processing plants transform live birds into frozen meat in approximately two hours. All the birds are inspected by federal inspectors for wholesomeness. If a problem is detected, the bird is either discarded or the questionable portions are removed. The birds are then chilled and when the body heat has been removed, they are graded on federal standards based on freedom from defects such as cuts, lost pieces of skin and parts. The turkeys are then ready for consumption. Only a few years ago turkeys were mostly limited to Thanksgiving and Christmas, but now turkeys and turkey products can be enjoyed every day of the year.

What has brought about this drastic change? For one thing, only about 40 percent of the turkeys sold these days are whole birds. The remainder appear in the supermarkets as packaged products that have little resemblance to the whole bird. This more convenient packaging and the inherent qualities of turkey meat (low fat—high protein) appeal to bargain-hunting consumers.

USU researchers have been instrumental in defining and capitalizing upon the versatility of turkey meat. Their creations include turkey: breast roast, hind quarter roast, precooked roast, steaks, burger, ham, salami, pastrami, bologna, and weiners. A machine was as crucial to this revolution as any human being. Developed by Beehive Machine Company of Salt Lake City, this deboning machine permits the recovery of more meat from the turkey carcasses. By coupling the availability of this deboned meat with research by USU personnel, the Moroni Feed Company has become the major producer of turkey weiners in Utah.

The Road Ahead

The future of turkey production is great on a national basis. The future role of *Utah* in this production game will be determined by how the industry solves its current and foreseeable problems. The energy now consumed during the brooding of turkeys must be reduced. Scientists and engineers at Snow Field Station and USU are developing plans to erect a building at Snow Field Station utilizing solar heat to supplement coal-fired furnaces, thus reducing the need for expensive fuels which are in short supply.

Dust and other pollutants must be controlled to reduce disease problems of turkeys, along with nuisance they create for some residents in the area. Possible solutions being tested include using water sprinklers or foggers, vegetative covers for the ground, and modifying the soil itself.

To meet the national demand for year-round fresh turkey and parts, Utah producers must raise their birds on a year-round basis rather than for the traditional seven or eight months. That means Utah producers must change their production habits and meet the needs of the birds as they occur on a year-round basis. Additionally, manufacturers of the further-processed turkey products must insure consumers of uniform quality in similarly named items. The stores that display turkey meats, processed or fresh, can probably be encouraged to enhance their consumer appeal.

On all these fronts, the established pattern of cooperation between USU and the industry will continue to develop efficient solutions.

ABOUT THE AUTHOR

Donald C. Dobson, Associate Professor of Animal, Dairy, and Veterinary Sciences, has conducted research and extensive studies with turkeys at Snow Field Station and is now serving as the USU Extension Poultry Specialist with an emphasis on egg production in chickens.

Photos in this article have been furnished by Dr. Robert Warnick, USU Associate Professor now heading the turkey research effort in Ephraim.

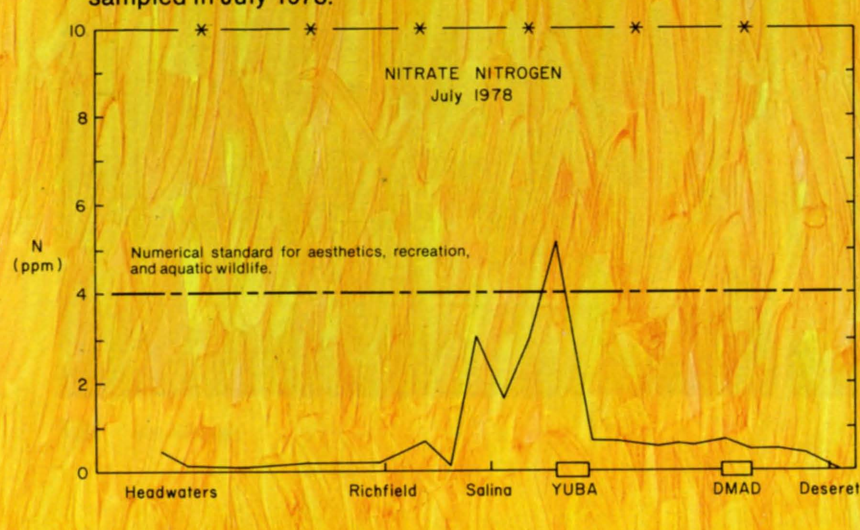
BELOW:

Converting feathered birds into packaged meat is a many stepped operation. From inspection through weighing, packaging, and eventually loading for shipment, it is people who insure the quality of the final product—consumer-ready turkeys from Utah.

Figure 1. Artistic interpretation of the Sevier River and its bordering lands showing acceptable and unacceptable levels of nitrate nitrogen concentrations.

*EPA LIMIT

Figure 2. Diagram representing nitrate nitrogen concentrations sampled in July 1978.



FERTILIZER NUTRIENT

SEVIER

If the national program to minimize agricultural pollution is to be effective, the control measures must be realistic and based on factual information. Problems should be adequately identified and practicable solutions developed. In the current Utah program, however, some problems have been presumed without data to support the assumptions.

Recent environmental planning reports (1) (4) (5) in Utah have cited the farm use of commercial fertilizer as a significant source of nutrient pollution in streams. But no reliable data were presented to support the claims. Furthermore, the allegations are not in harmony with research involving the use of commercial fertilizers in other states (3).

The study reported here was undertaken to determine whether the use of commercial fertilizers in the Sevier Basin was contributing plant nutrients to the river.

Why the Sevier?

The Sevier River was selected for several reasons. Agriculture in the Sevier River Basin is representative of much of the agriculture in Utah. Most of the valley land next to the river is irrigated. There is little industrial or urban development.

The stream supplies water for approximately 20 to 25 percent of the irrigated acreage in the state. The agricultural areas have been naturally defined into conveniently identifiable stream flow units. The river and its main tributaries traverse 200 to 300 miles and the entire river system lies within Utah.

Beginning in high mountain valleys and ending in the Sevier Lake, the basin's water is diverted and re-diverted

P. D. CHRISTENSEN,
R. E. LAMBORN,
and R. F. NIELSON

LEVELS IN THE RIVER

Figure 3. Acceptable and unacceptable levels of phosphorus concentrations.

*EPA LIMIT

Figure 4. Diagram representing phosphorus concentrations sampled in July 1978.

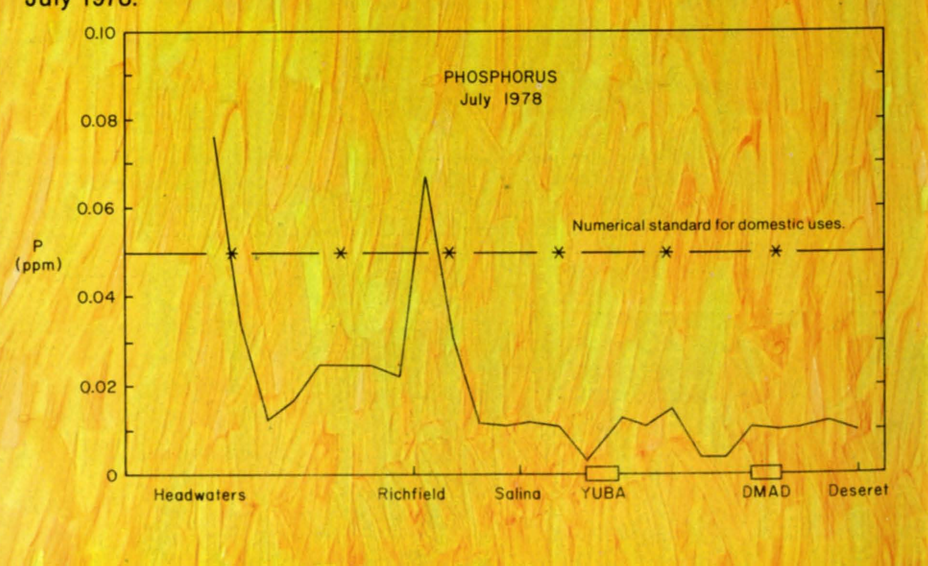


Table 1. NITROGEN, PHOSPHORUS, AND POTASSIUM IN THE SEVIER RIVER AND ITS TRIBUTARIES—MID-OCTOBER 1977, MID-MAY AND MID-JULY 1978

Sample Number	Location	Phosphorus P Oct	May	July	Potassium K Oct	May	July	Nitrogen NO_3 Oct	May	July	Electrical Conductivity EC x 106 Oct	May	July
MAIN STEM—FROM HATCH TO DELTA			ppm			ppm			ppm			micromhos/cm	
22	Hatch	.01	.013	.012	1.2	1.6	3.9	.02	2.6	<.1	338	233	267
21	Bryce Canyon Jct.	.01	.010	.010	1.6	2.3	3.9	.01	.28	<.1	352	252	273
20	Panguitch area	.01	.006	<.005	3.9	2.0	3.9	.75	.12	.4	515	278	389
19	S. Circleville Canyon	.01	.007	<.005	3.9	2.0	3.9	.36	.24	.2	472	286	392
18	Circleville area	.02	.019	<.005	3.5	2.0	3.9	.23	.31	<.1	447	277	392
23	Kingston	.00	.031	.012	5.5	3.1	3.9	1.64	.54	1.7	555	306	521
24	Piute Reservoir	.03	<.005	.013	5.1	4.3	3.9	.31	.13	.1	500	428	306
25	Marysvale	.04	<.005	.017	4.7	4.7	3.9	.09	.17	.1	485	459	379
27	Joseph	.02	.009	.025	4.3	3.5	3.9	.01	.14	.2	454	352	333
28	Elsinore	.02	<.005	.025	4.7	3.5	3.9	.94	.17	.2	549	368	361
29	Austin	.01	.007	.025	4.7	3.5	3.9	1.13	.26	.2	549	367	367
30	Annabella	.02	.007	.022	4.7	3.5	3.9	1.09	.22	.1	562	367	359
32	Richfield	.02	.044	.070	6.2	3.9	3.9	.59	.23	.3	1440	513	740
11	Sigurd	.04	.016	.031	6.2	4.3	7.8	.99	.33	.7	1020	641	976
10	Rocky Ford Reservoir	.03	.006	.012	6.2	5.5	7.8	1.23	.13	.1	984	781	819
8	Salina	.05	.007	.011	9.0	6.2	7.8	2.78	.42	3.0	2150	1075	1940
6	Redmond	.03	<.005	.007	9.0	5.1	7.8	2.82	.46	2.9	2000	800	1840
4	Gunnison	.02	.006	.011	8.6	5.5	7.8	2.68	.63	3.0	2410	1053	2720
1	Fayette	.01	.009	<.005	8.6	5.1	7.8	3.17	.93	5.1	2630	1032	3060
33	Yuba Dam	.02	.007	.013	9.8	7.8	7.8	.21	.92	.7	2500	2304	1840
34	W. of Yuba Dam	.02	<.005	.011	3.9	7.8	7.8	.66	.87	.7	980	2187	1720
36	Mills	.02	<.005	.015	3.9	7.8	7.8	.45	.94	.6	960	2234	1800
39	N.E. Lemington	.02	<.005	<.005	4.7	7.4	7.8	.27	.80	.6	1090	2196	1200
38	Lemington area	.03	.007	<.005	5.5	7.4	7.8	.26	.84	.6	1220	2206	1690
37	Lynndyl	.02	.012	.011	6.6	7.4	7.8	.43	.87	.7	1570	2132	1800
40	N.E. Delta	.02	<.005	.015	7.4	7.4	7.8	.07	.71	.5	1600	2056	1730
41	Delta	.02	.007	.011	6.6	7.8	7.8	.03	.73	.5	1420	2124	1770
44	Deseret	.01	<.005	.010	12	10.5	15.6	.12	.25	.1	5000	5526	4210
45	W. of Hinckley	.01	<.005		15	18.3		.10	.19		5000	9016	
CANALS IN DELTA AREA													
46	DMAD outlet	.03	<.005	.010	7.0	7.4	7.8	.06	.64	.5	1520	2072	1820
42	B-2 Canal (DMAD)	.02	.006	.010	7.0	7.4	7.8	.09	.73	.5	1440	2072	1770
43	Deseret lowline (Delta)	.02	<.005	.012	9.0	7.8	7.8	.05	.59	.4	2020	2215	2000
54	Ditch S. of Deseret		<.005	.007		7.8	7.8		.52	.3		2234	1840
SEVIER TRIBUTARIES													
	East Fork of Sevier												
50	Bryce Canyon		<.005			.8			.00			428	
49	Widstoe		.105			1.2			.09			227	
48	S. of Antimony		.100	<.005		2.0	3.9		.20	.5		229	350
16	Antimony	.05	.086	.076	3.9	2.3	3.9	.16	.16	.2	391	198	376
17	Kingston	.01	.032	.034	4.7	3.9	3.9	.02	.06	.1	542	435	399
Grass Valley													
12	Koosharem Reservoir	.20	.058	.052	6.2	5.1	3.9	.28	.06	.1	313	278	267
13	Otter Creek, Koosharem	.03	.010	.040	11	5.5	3.9	.15	.14	.1	569	504	316
14	Otter Creek, S. of Koosh.	.01	.016	.012	5.5	5.1	3.9	.03	.01	<.1	363	414	220
15	Otter Creek Reservoir	.13	.022	.012	5.5	4.3	3.9	.02	.04	.1	490	408	323
Grass Valley													
26	Sevier	.03	.031	.015	2.7	2.7	3.9	.10	.20	.2	312	165	151
Clear Creek													
9	Salina	.02	.019	.007	3.9	3.5	< 3.9	.05	.28	.3	714	407	459
Redmond Lake													
5	Redmond	.02	<.005	.013	7.0	7.4	7.8	.44	.14	.3	970	994	909
Sanpete													
2	Nine Mile Reservoir	.01	.009	.010	6.2	4.7	3.9	.71	.56	.3	1420	1137	805
3	Gunnison Reservoir	.02	.009	.010	9.0	6.6	7.8	.27	.37	.3	2730	1855	1390
47	Manti Creek, Manti		<.005	<.005		1.6	< 3.9		.25	.1		495	410
Chicken Creek													
35	Chicken Creek Reservoir	.03	<.005	.026	8.2	9.0	11.7	.15	.15	.1	2810	3893	4170
CITY SEWERS													
7	Salina	1.99	2.70	4.50	13	10.5	15.6	7.47	5.9	12.8	752	659	936
31	Richfield	1.99	2.93	4.14	11	10.5	11.7	2.59	.5	2.1	1020	1187	1010
SMALL TRIBUTARIES													
51	Marysvale Canyon		.007	.007		.8	< 3.9		.11	.1		214	127
52	Richfield—Canyon NW		<.005			3.1			.25			389	
53	Oak Creek, Oak City		<.005	.011		1.2	< 3.9		.13	.3		253	302

many times as the surface runoff and subsurface drainage returns to the river. By this process, the water is "recycled" through irrigated farm soils five to ten times and the irrigation efficiency for the total river basin approaches 98 percent. All these factors made the Sevier River appear to be a good stream to investigate relative to nutrient pollution from agriculture.

Procedure

The Sevier River and its tributaries were sampled at 54 locations; from the headwaters near Bryce Canyon National Park and Cedar Breaks National Monument to the stream below the last farms in the Delta-Deseret area. Samples were taken from many stream segments, all the major irrigation storage reservoirs in the Basin, and two city sewer outlets. Forty-six locations were sampled October 11-12, 1977. The same and eight additional locations were sampled May 16-17 and July 10-12, 1978.

The October sampling occurred near the end of a prolonged drought and represented the low-flow situation in the river. At this low stage, a high percentage of the stream consisted of subsurface drainage. Surface runoff, if any, was small. The October samples, therefore, should reflect any nutrient pollution from fertilizers that leached through the soil.

The May sampling was taken during the spring runoff. The water samples represented near maximum flow conditions in the river, particularly since the previous late-winter precipitation had approached record-high levels. Much of the stream flow came directly from snow melt in the mountains and contained sediments from forest and rangelands. This high sediment level, which is characteristic of the spring runoff period, involved essentially no erosion from farmlands.

The July sampling was accomplished near the peak of the summer irrigation season when any pollution from field runoff would probably be at its highest.

Water samples were taken and chemical analyses made according to standard research procedures. All water samples were analyzed for nitrogen, phosphorus, potassium, and total salts.

Results and Discussion

Results of the chemical analyses are given in Table 1 and shown in Figures 1 through 4.

NITRATE

Water samples from the Sevier River and its tributaries, including several samples from canals, contained 0.00 to 5.1 parts per million nitrate nitrogen. Of 144 samples analyzed, only 13 exceeded 1 ppm. Twenty-five samples from the main stream of the river, six canal samples, and two samples from Nine Mile Reservoir were in the range of 0.5 to 0.99 ppm. There was no apparent relationship between commercial fertilizer use and nitrate in the water.

The highest nitrate levels were in the samples from the Salina to Fayette reaches of the river, where animal wastes from feedlots may have entered the stream. Below Fayette, all samples contained less than 1 ppm nitrate nitrogen. In contrast, effluents from city sewage plants varied from 0.5 to 12.8 ppm nitrate nitrogen. All sewage samples except one contained more than 2 ppm nitrate nitrogen.

PHOSPHORUS

Phosphorus levels in the river and its tributaries varied from less than 0.005 to 0.13 ppm. Only three samples tested at or above 0.100 ppm. These three samples had been taken from Otter Creek Reservoir and the South Fork of the Sevier above Antimony. Most of the samples tested at below 0.05 ppm in phosphorus content. The overall trend was toward decreasing phosphorus going down the river. Samples of the effluent from the sewage treatment plants ranged from 1.99 to 4.50 ppm phosphorus.

POTASSIUM

Potassium in the water samples tended to increase as the return flow from subsurface drainage increased. Since applications of potassium fertilizer would be rare on farms in the Sevier Basin, the element was judged to have come from the soil minerals. The same trend in potassium content has been apparent for years (2).

SALT CONCENTRATION

Salt (total dissolved minerals) concentrations in the Sevier River, as shown in the data, increase as the river descends from its source in the mountains. This pattern has likely persisted since geologic time. Consumption of water, whether by irrigated agriculture, reservoir evaporation, forest and range plants, or evapotranspiration from marshy wildlife areas along the river, concentrates the salt in the water. Irrigated agriculture has probably accentuated this trend, but the use of commercial fertilizers has been unrelated to salinity levels.

Conclusions

Chemical analyses of water samples taken at three periods from the Sevier River and its tributaries gave no indication that the use of commercial fertilizers alters the nitrogen, phosphorus, or potassium levels in the stream. There was some evidence, however, that the practice of irrigation tends to remove phosphorus, and possibly nitrate, from the stream.

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Large, mature spruce and fir trees use about 3,000 gallons/acre/day in the summer.

Clearcut areas use about 600 gallons/acre/day in the summer which could possibly free 2,400 gallons/acre/day for other uses.

GEORGE E. HART and DAVID A. LOMAS

CLEARCUTTING

INCREASES SOIL MOISTURE IN ENGELMANN SPRUCE FORESTS

VIRTUALLY ALL usable streamflow in Utah originates from forests and rangelands of the high mountains. Trees are voracious consumers of water; with a single large conifer tree, under ideal conditions of moisture and climate, being able to transpire 50 to 100 gallons of water per day. Because this water is returned to the atmosphere as vapor, it is not directly available to recharge soil moisture and to supply streamflow. It has been conclusively demonstrated that reducing transpirational losses by complete or partial cutting of forest stands increases streamflows in humid regions. Less is known about how timber cutting affects water yields in drier climates.

One way of studying this problem is to compare the rates of soil moisture loss during a growing season on neighboring cut and uncut areas. Using this approach, it was found that clearcutting aspen in Davis County reduced soil moisture loss by about 6 inches (Johnston 1970). In contrast, clearcutting lodgepole pine in the Uinta Mountains reduced moisture loss by 2 to 5 inches (Johnston 1975). A one-inch increase in soil moisture converts to an increase of 1/12 acre-foot in streamflow for each acre treated.

To extend these data, we (Eaton 1971, Rosquist 1973, Lomas 1977) studied soil moisture depletion before and after clearcutting in a mature stand of Engelmann spruce and subalpine fir in the Bear Range of the Wasatch Mountains in northeastern Utah. The spruce-fir forest is an important resource in the middle and southern Rockies, covering about 5 million acres and representing 18 percent of the region's commercial timber area.

The stands selected for study were at 8,700 feet (2650 meters), where annual precipitation averages 40 inches and about 90 percent of it comes as snow. Four circular plots were established and soil moisture measurements were taken with a neutron meter at 15 to 20 locations within each one-acre plot. The intensive sampling with a precise instrument produced reliable data on the moisture content of the upper 6 feet of soil. Numerous measurements were taken during the growing seasons from 1970 through 1975, while the forest cover was dense (34,000 to 42,000 board feet per acre). This five-year calibration period was to underlay our development of statistical equations which would predict soil moisture losses on the plots before clearcutting. From the 1970-75 information, we found that statistical significance could be given to any post-cutting increase in soil moisture that exceeded 0.9 inches per season.

During October 1975, three of the plots were completely clearcut and merchantable logs were removed. Logging slash was also removed from each measurement area and piled on the edge of the plot. Snow surveys were taken in the winter of 1976 on the cut plots and on the forested plot. We measured soil moisture content every two weeks between June 18, 1976 and September 22, 1976.

The soil moisture on the clearcut plots was greater than on the forested plot, indicating that clearcut logging had drastically reduced transpirational losses. From the calibration data, we predicted what the moisture loss would have been in 1976 if the plots had not been cut. The difference between predicted and measured losses (Table 1) represents the savings in water use due to clearcutting. These savings (or increased moisture levels) are much larger than the 0.9-inch value needed for statistical significance.

The significant first-summer increases in moisture content (8 to 10 inches) on spruce-fir plots are considerably more than comparable increases found after clearcutting aspen or lodgepole pine. This greater soil moisture is probably due to the spruce-fir being so much larger and deeper-rooted than aspen and lodgepole pine, and to their retention of year-around foliage. The amount of water transpired would therefore be greater and, their removal would allow more moisture to remain in the soil than when aspen or pine are clearcut.

The snow surveys indicated that a much deeper snowpack developed in the clearcut areas than under the spruce-fir stand. Before cutting, snow accumulation had been essentially the same on the four plots, but after clearcutting there were 35 to 37 inches of snow water-equivalents at the peak of accumulation as compared with 24 inches on the forested plot, a significant difference. Numerous studies have shown somewhat deeper snowpacks on cutover areas than under adjacent forests, due to the removal of the intercepting forest canopy. The magnitude of the increased pack (12 inches of water equivalent or 50 percent) which we observed was surprisingly large. And we believe that some of this increase was caused by the air turbulence the small (1 acre) circular clearcuts created above the canopy. Cutting patterns that produce numerous, but small (1/4 to 1 acre) openings appear to optimize conditions for locally augmenting snowpack in coniferous forests. As the openings become larger, snow trapping by turbulence becomes less effective; and, in openings that exceed about 50 acres, there may be less snow accumulation because of the exposure to winds that carry the snow into adjacent forests.

The results of our controlled field experiment show that soil moisture


Engelmann spruce stands in summer and winter before clearcutting.

George Hart checks water measurement instruments in a clearcut area.

Dave Lomas measures snowpack water equivalent with a snow tube.

Snowpack was 50 percent greater in clearing than in the forest.

Table 1. First-year savings in moisture use on clearcut plots expressed in inches per season in a six-foot profile.

	Plot 1	Plot 2	Plot 3
Predicted loss	10.3	11.7	11.5
Measured loss	2.4	1.7	2.4
Savings	7.9	10.0	9.1

losses were reduced by about 80 percent (8.5 inches), while snow accumulations increased by about 50 percent (12 inches) in completely clearcut, one-acre plots of mature spruce-fir. These figures should not be interpreted, however, as meaning that substantial increases in streamflow would result from clearcutting in the spruce-fir type. Too many of the variables argue against such projections.

First, it wouldn't be economically feasible to cut such small areas, and with larger cutting blocks both the increase in snowpack and the enhancement of soil water retention would be lessened. Second, we chose exceptionally dense stands for our experiment, and they were harvested completely. Commercial operations would have to include stands of considerably lower volumes (roughly 20,000 board feet/acre) and of poorer quality; quite a few unmerchantable trees would therefore be left standing. Third, forests and meadows present a mosaic pattern on high elevation lands, with forests sometimes occupying only one-third to one-half the area of a drainage basin. Thus, any increase in water yield at the drainage outlet would be in proportion to the area of the drainage that was harvested. Finally, soil texture and conductivity vary greatly within a drainage and pathways of subsurface water movement are complex. In other words, the ultimate fate of the substantial surpluses of water that can be produced on-site in small clearcuttings would depend mostly on whether the water was utilized by vegetation downslope or whether it moved directly into small stream channels and became part of the drainage network of the basin.

These considerations prompt us to suggest that it would be the enhanced snowpack and its runoff, not the increase in summer soil-moisture content produced by clearcutting operations that would contribute most to any water-yield increase realized on an overall drainage basin.

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George E. Hart has degrees in Forestry and Forest Hydrology from the University of Michigan. Formerly a hydrologist with the U.S. Forest Service in New Hampshire, he is presently associate professor in the Department of Forestry and Outdoor Recreation, with interests in soil erosion and water quality.

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PROJECTS IN PROGRESS

TESTING TOGETHERNESS ON THE RANGE

IN THE EARLY 1800s, Westerners backed their convictions about sheep and cattle with bullets. As the West gradually evolved a somewhat less violent culture, at least one of these convictions was transformed into a truism. Everybody who was at all concerned, somehow just *knew* that rangeland could support either sheep or cattle—but NOT both.

One of the earmarks of our scientifically enlightened age, however, is the periodic questioning of truisms. And so, eventually, the compatibility of sheep and cattle as grazing partners was both recognized *and* put to work. Now, 1979 has become year 1 (of 10) in a research effort to prove (or disprove) the suspicion that if you graze sheep and cattle together, you can optimize red meat production per acre of rangeland.

The research is being done on approximately 6,000 acres of high (8000- to 8500-foot) elevation, summer (ca. June 10 to October 10) range near Cedar City, Utah. Darrell H. Matthews is leading the livestock investigation, while James E. Bowns heads up the range work. For both scientists, this first year has been filled with the frustrations of preliminary "getting ready" steps.

Accurate checking of their major variables (continuous versus rotation grazing by: sheep alone, cattle alone, or sheep and cattle together) requires 18 units of pasture. To establish those units, the researchers had to have over 18 miles of fencing strung. They also had to make sure that each of the units included a reliable source of water. With those details out of the way, they began determining how many animals could graze each pasture without overstressing the vegetation.

Based on their 1979 results, they plan to run a total of 126 mature Hereford and Herford-cross grade cows and 630 mature ewes of various breeds in the years ahead. By managing their cows and ewes as a private enterprise would, Bowns and Matthews expect to produce results that can be readily applied by the livestockmen who are using the thousands of acres of comparable rangeland in the West. In particular, the researchers will be defining the maximum cattle/sheep carrying capacities that are consistent with perpetuating the vitality of the range itself.

According to Matthews, "Even before we finish out the tenth year, we ought to be able to make management recommendations. Our data on calf and lamb weights, wool production, and adult animal reproductive performance will be combined with forage measurements (range productivity, grazing use of plant species, any changes in plant species populations per pasture). By integrating these facts with operating and investment cost figures, we can give ranchers a reliable basis for choosing between rotation and continuous grazing patterns. They can also use our results to evaluate how much of a profit advantage (saleable products produced per acre) they might gain by running sheep and cattle as grazing partners."

LOIS M. COX

A GRASS IS A GRASS IS A... OR IS IT?

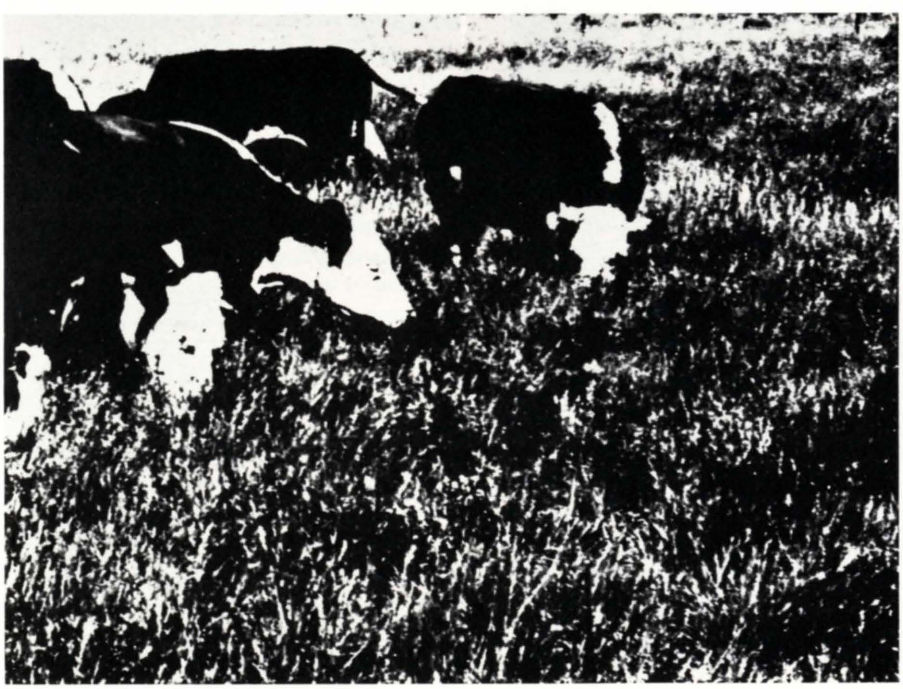
IT DEFINITELY *ISN'T,* if you pay attention to how cattle graze. If you and I were to stand in a field populated by clumps of crested wheatgrass, we'd probably not be aware of any substantial differences among them. Turn in some cattle, however, and they would quickly identify some of the plants as gourmet fare and others as totally unacceptable.

The most peculiar part of this discrepancy, according to B. E. Norton (Research Assistant Professor of Range Science), is that it has been recognized for years without being investigated definitively. "The situation," he said, "is a bit like much of life in general. We have to break from our habitual ways of thinking to see the importance of what we tend to take for granted because it is going on all the time." He and his technician (Pat Johnson) are making *their* break with 294 pasture plots, cattle, and two seasons' worth of every-other-day, detailed-observation diaries.

Norton's non-traditional look at cattle and range grass is part of a 10-year comprehensive research effort on 24 contiguous fenced pastures of 28 hectares (70 acres) each near Eureka in Juab County. These same parcels of BLM land were the site of some of USU's precedent-setting range research of the 1950s and 1960s.

The 1979 through 1989 program will have a team of eight professionals in Range Science and their graduate students coordinating a variety of their own "things" on this intermediate elevation (1,500 to 1,950 meters or 5,000 to 6,400 feet) spring/early summer rangeland. By blending their special abilities and interests, they expect to help ranchers break the spring forage bottleneck. Success will mean an easing of the ranchers' persistent dilemma—how to get animals off hay and on the range as early as possible, without damaging the vegetation. That, in turn, would mean a better meat supply at the supermarket.

"This first (2-year) phase of our contribution to the overall program," explained Norton, "should give us baseline information about how cattle actually use stands of crested wheatgrass. But what we saw in 1979 raised more questions than it answered. The cattle virtually ignored both the very large and the very small clumps of grass, while heavily grazing the middle-sized plants."



Norton went on to state some of the obvious (and not-so-obvious) questions that the observed grazing pattern had posed. Among them were: Why do the cattle favor the middle-sized plants? Does it have something to do with the way they look or taste, or is it related to the mechanics of grazing? Does heavy grazing of certain plants throughout one season force the use of other grass clumps the next year? Would running cattle and sheep together, or putting a few more cattle on the land, or grazing earlier in the spring, encourage a less selective grazing pattern?

Their first year of data also alerted Norton and Johnson to disturbing implications about the reliability of standardly accepted techniques of evaluating range use. As Norton stated it, "Our normal ways of measuring the degree of use given a particular range generally miss any variations in the intensities with which cattle may graze different plants of the same species. We'll know more after another year of data collecting—but it does look suspicious. Based on our 1979 conditions, an apparently ideal 50 percent utilization of a range as a whole could include severe over-grazing of certain plants (the most desirable), which may then die. That would leave the range less able to sustain grazing the next year than a 50 percent utilization would suggest.

Only more time will give Norton (and the other Juab County range researchers) the answers they want. Meanwhile, ranchers and potential consumers of beef will have to be satisfied with gradually extended insights in the perplexing interspecies behavior of cattle and grass.

WHO DOES WHAT FOR WHOM?

ONE THING FOR SURE, when the question centers around lodgepole pine, mountain pine beetles, and various species of blue-stain fungi, the trees are done to, not for. Beetle epidemics are devastating western forests of lodgepole pine. And where the beetles go—so do the fungi. Other certainties include the beetles' preference for large, vigorous, over 60-years-old pines, and the almost invariable, quick death of any tree they attack. Among the unknowns are: what do the fungi and beetles see in one another, and how can tree survival be enhanced.

As part of a continuing effort to come to the defense of lodgepole pines, the U.S. Forest Service funded a USU research project into the beetle/fungi/tree interactions. The cooperative (Walter E. Cole of the F.S.'s Intermountain Forest and Range Experiment Station; Michael A. Walsh, Assistant Professor of Biology; and Richard Ballard, a graduate student) venture began in 1978 with Walsh and Ballard reviewing what had already been learned by other researchers.

"An association of beetles and fungi," said Walsh, "is not unusual. Some closely related beetles seem to actually run fungi farms, cropping the plants as food. The reasons for other affiliations, such as the one between the pinebark beetle and the fungi that produce a blue dye, are less easily defined. Investigators who worked on the problem in past years, found that the blue-stain fungi were visibly co-existing with the beetle and its larvae only at certain developmental stages of the insect."

When asked if the trees were totally defenseless, Ballard replied, "No, and in fact, their defense mechanisms are of prime research interest to us. When attacking beetles first encounter resin ducts in a tree, some of them may be drowned by the tree's automatically generating an extra flow of resin, which ejects the insects via what we call pitch-

out tubes. Resin also contains toxins that can limit fungal growth. In other cases, the tree may produce special cells that wall off the beetle-introduced fungi. An infected tree may alter its water conduction routes to bypass fungal invaders. The trouble is, none of these defenses has much lasting value. And one of them, the production of profuse resin, sometimes seems to contribute to the ultimate death of the tree."

Walsh then explained that the resin-producing system of any tree operates through both vertical and horizontal ducts. The horizontal segment develops in the ray parenchema, which is where the fungi thrive. Apparently, as the female beetles create their egg/larvae galleries and the fungi spread around the tree's circumference, the resin systems of some pines shift into a high-gear productivity. The results include not only the death of some beetles and fungi, but an inadvertent, drastic interference with the tree's water conduction—and thus a sort of suicide.

Responding to another question, Ballard commented, "We are comparing the anatomy and physiology of diseased and non-diseased trees in Logan Canyon. Our main goal is to trace the interactions as the blue-stain fungi spread through the tree. We also want to observe (via the electron microscope) whatever anatomical alterations the tree undergoes throughout the beetle/fungi invasion. If we can recognize and measure physiological changes too, we should eventually be able to understand how the beetles and fungi help one another while simultaneously killing their host."

By learning more about the beetle/fungi cooperative arrangements, the researchers expect to identify ways the trees can be helped to defend themselves against the twosome. Once again, it seems to be a case of having to get to know your enemy before you can do effective battle.

1979 INDEX

UTAH SCIENCE

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